Temperature and water vapor variance scaling from AIRS, climate models and in situ observations

B. H. Kahn[1], J. Teixeira[1], E. J. Fetzer[1], A. Gettelman[2], S. M. Hristova-Veleva[1], X. Huang[3], A. K. Kochanski[4], M. Köhler[5], S. K. Krueger[4], R. Wood[6], and M. Zhao[7]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
[2] NCAR, Boulder, CO, USA
[3] Dept. of Atmos., Ocean and Space Sci., University of Michigan, Ann Arbor, MI, USA
[4] Department of Atmos. Sci., University of Utah, Salt Lake City, UT, USA
[5] ECMWF, Reading, England
[6] Department of Atmos. Sci., University of Washington, Seattle, WA, USA
[7] GFDL, Princeton, NJ, USA

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Research Thrusts

- **Scale dependence of temperature & water vapor variance**
    - Satellite observations: Atmospheric Infrared Sounder (AIRS)
    - Free-running climate models: NCAR CAM3 and GFDL C180HIRAM2.1
    - Models with data assimilation: ECMWF (YOTC) and MERRA
    - Cloud-resolving model: Mesoscale Modeling Framework (MMF)
    - Aircraft observations: VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS)
- **Implications for future satellite observations of temperature & water vapor**

<u>Take Home Messages</u>

- **AIRS scaling reveals lots of regime structure in *T* and *q***
  - This perspective provided **<u>only</u>** by sat obs

- **Comparisons of AIRS to Models**
  - All models have scaling exponents that are too steep
  - “Free-running” models have slightly steeper exponents than those with “data assimilation”

- **Scale breaks at scales below AIRS in models and obs**
  - MMF model shows CWV break around resolution limits of AIRS
  - VOCALS *T* and *q* have increasing slopes below 10–20 km

- **Need higher spatial resolution sat obs – not planned for NPOESS era**
  - Scale-dependent variability – is the “turbulence” right in climate models?

Mesoscale Spectra – A fresh look at an old problem

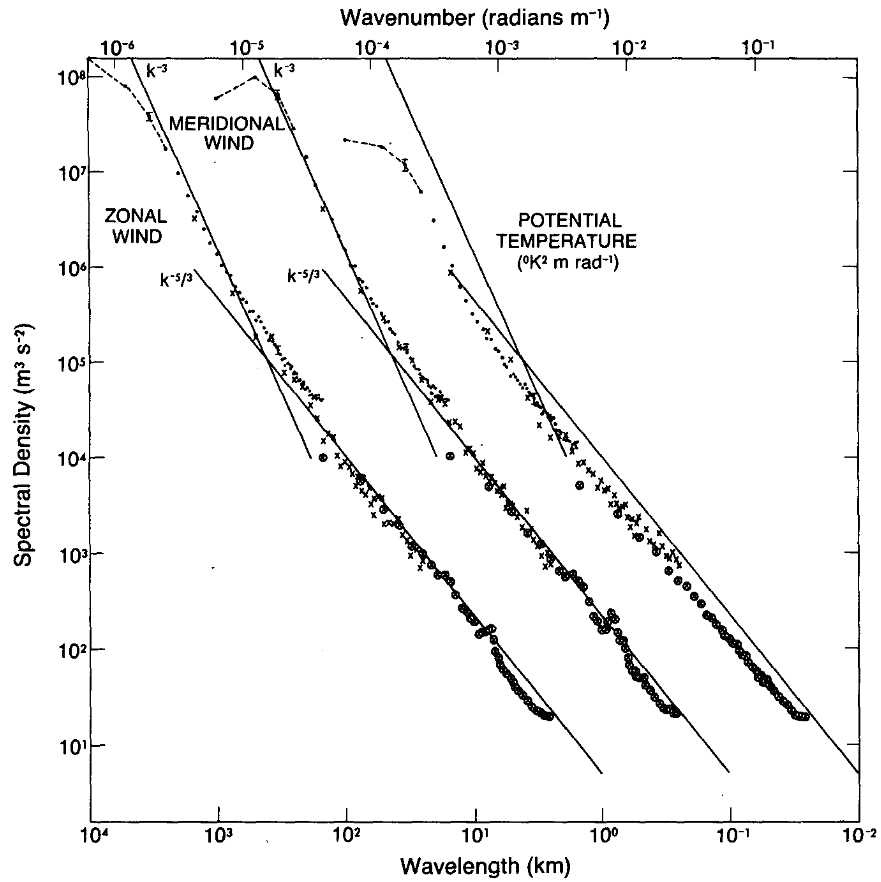
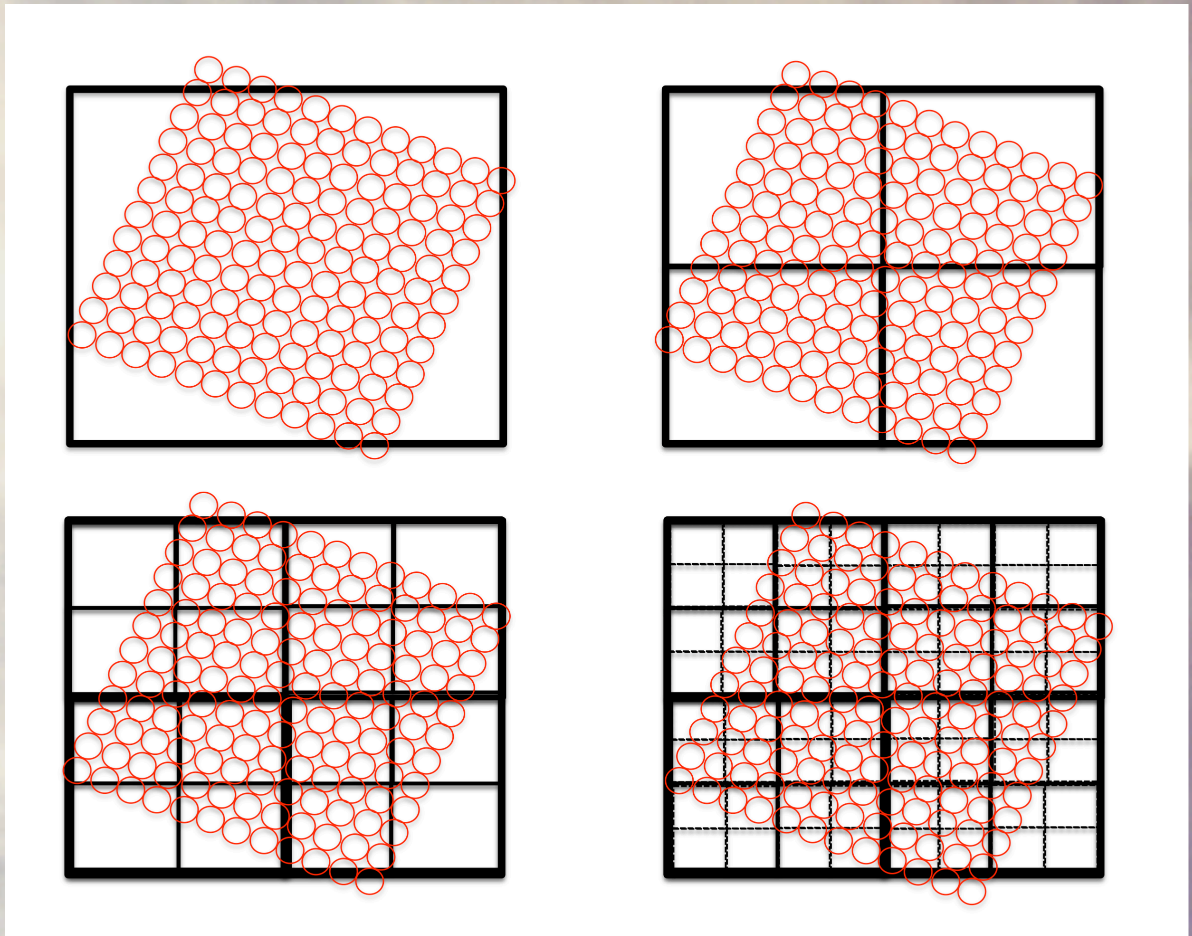


FIG. 3. Variance power spectra of wind and potential temperature near the tropopause from GASP aircraft data. The spectra for meridional wind and temperature are shifted one and two decades to the right, respectively; lines with slopes -3 and $-5/3$ are entered at the same relative coordinates for each variable for comparison.

Nastrom and Gage [1985]

“Poor Man’s” Power Spectral Analysis



Variance scaling exponents of 1.0, 0.5 and 0.33 ≅ –3, –2, and –5/3, respectively

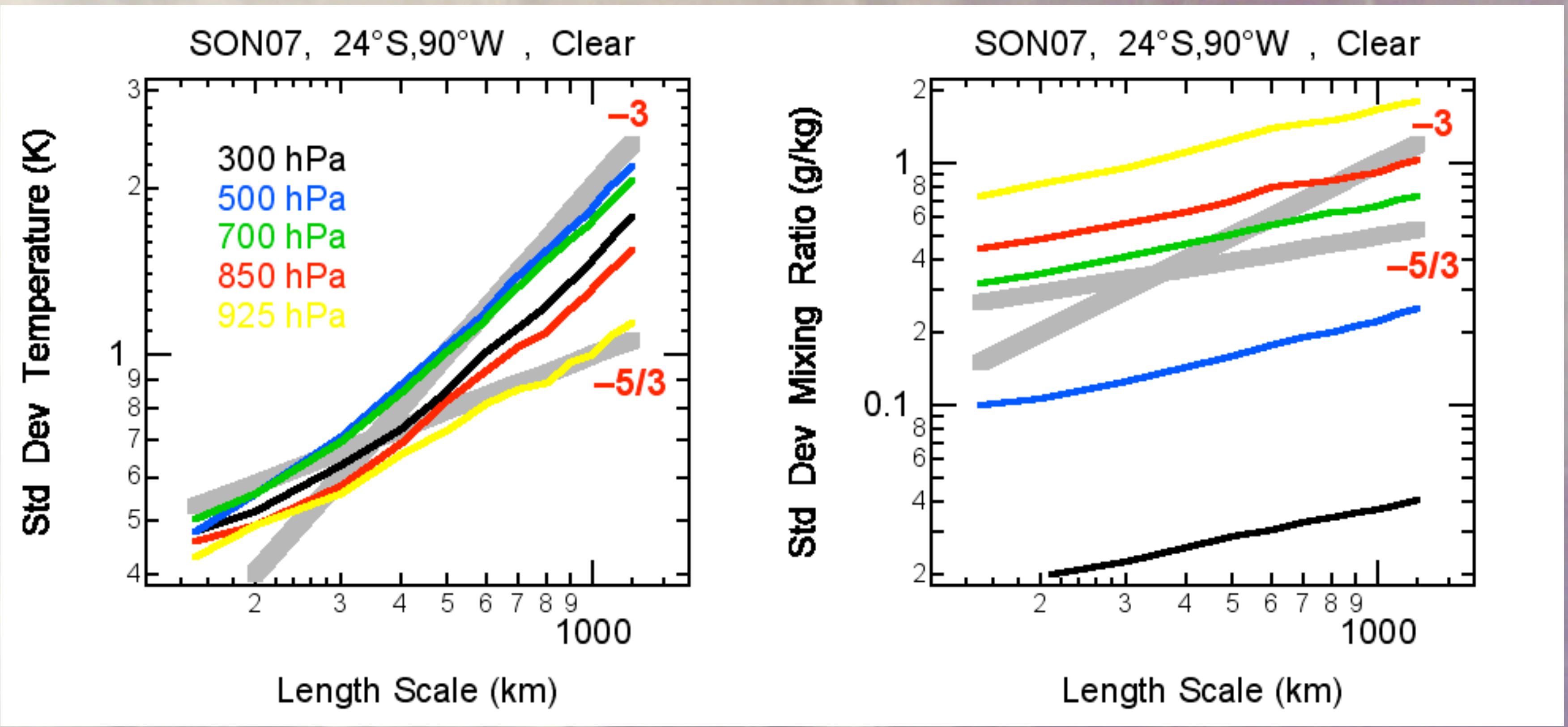
Daily ‘snapshots’ averaged to season

Variance calculated for 1.5, 2.0, 3.0, 4.0, 6.0 and 12.0° boxes

Results for “clear-ish” skies only: ECF < 0.1 for AIRS and CF < 0.5 in models

Kahn and Teixeira (2009), *J. Climate*

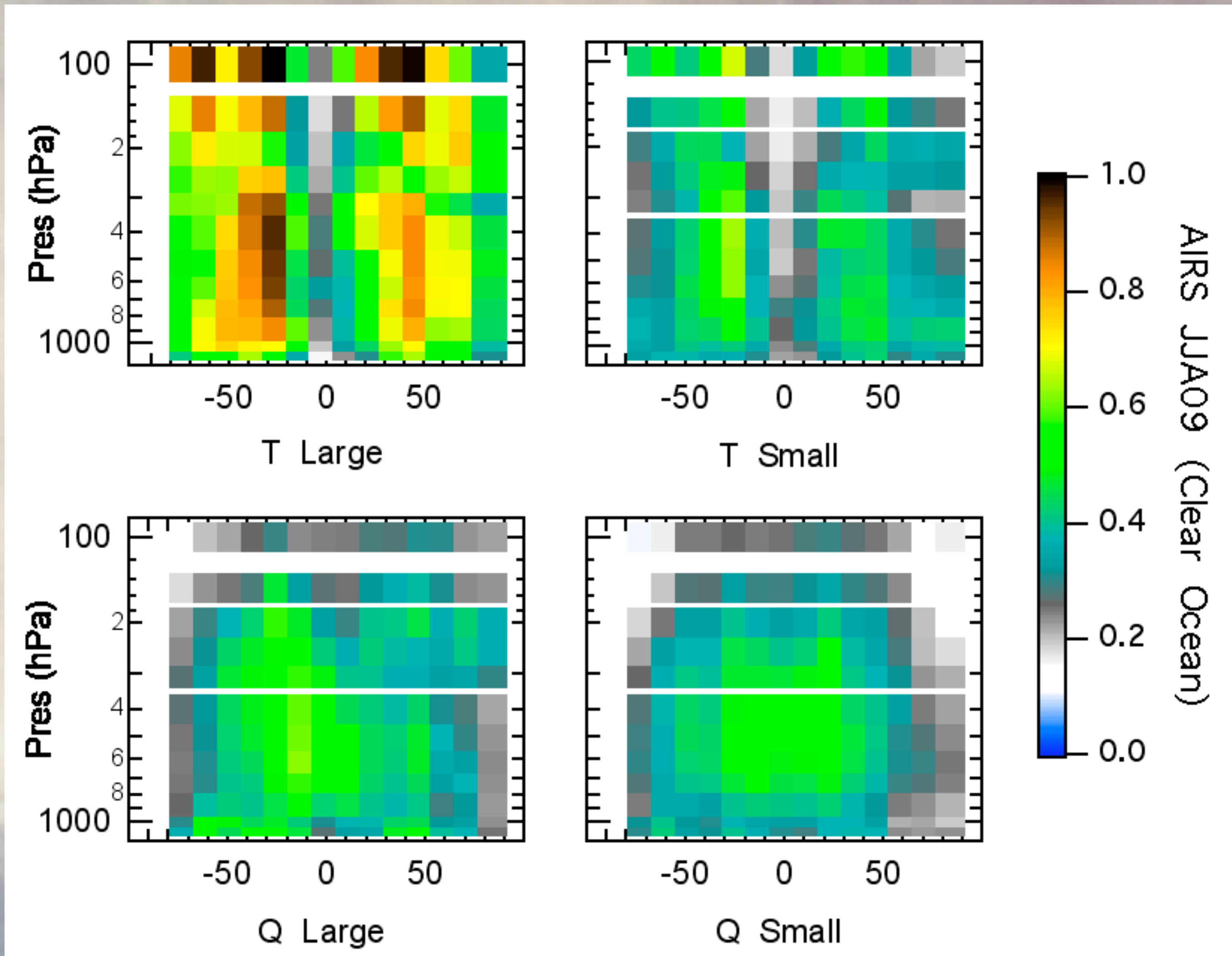
Scaling exponents & breaks observed with AIRS



Variance scaling/structure function exponents of 1.0, 0.5 and 0.33 ≅ –3, –2, and –5/3, respectively

Kahn and Teixeira (2009), *J. Climate*

Mesoscale break for *T* – not for *Q* – in AIRS



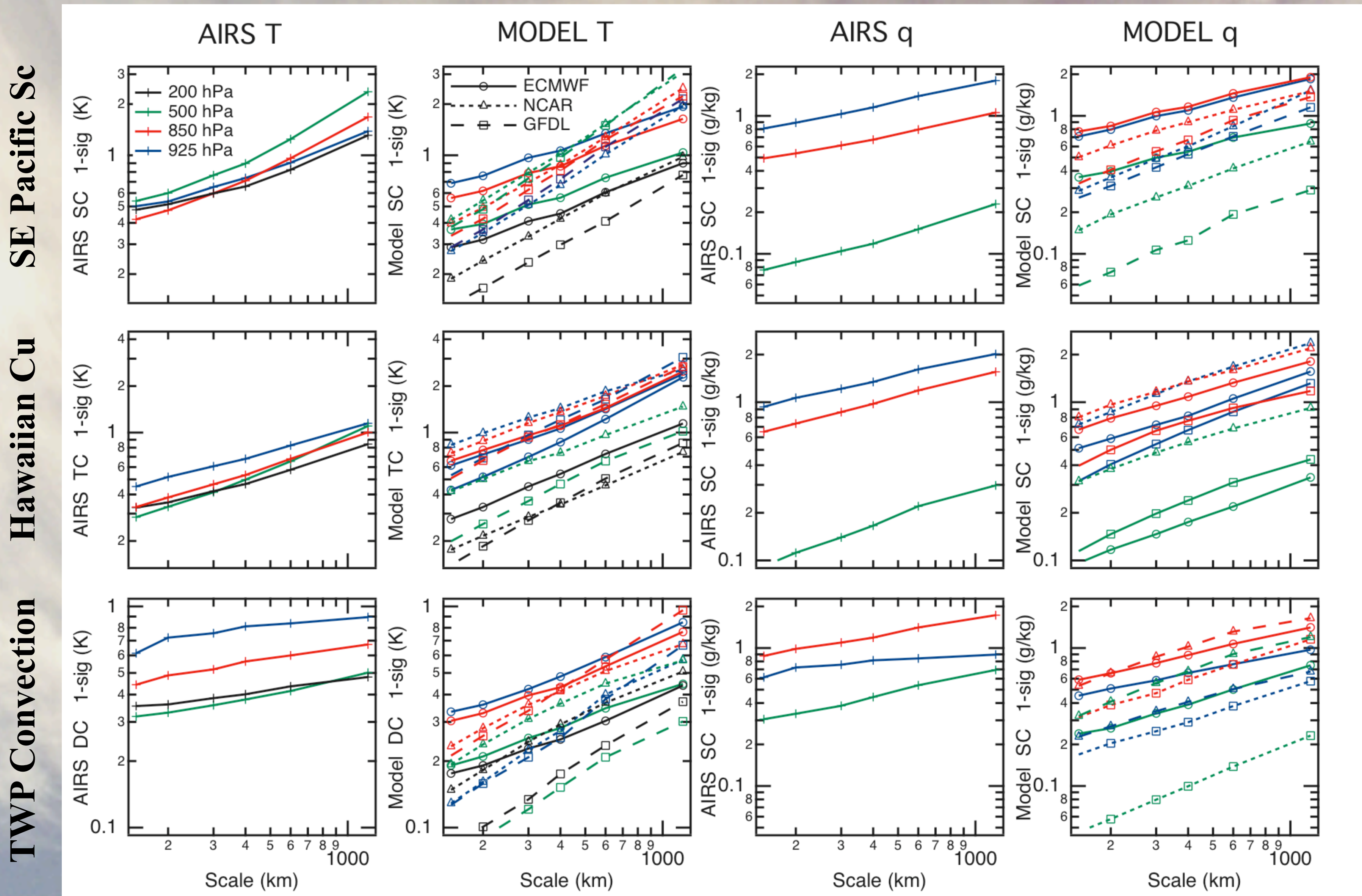
Kahn and Teixeira (2009), *J. Climate*

Models Used in this Comparison

Model	Resolution	Data assimilation?	Simulation Period
GFDL C180HIRAM2.1	0.5° × 0.625°	NO	01 September 1995 – 30 November 1995
NCAR CAM3	0.31° × 0.23°	NO	01 June 2005 – 31 August 2005
ECMWF (YOTC)	0.5° × 0.5°	YES	01 June 2009 – 31 August 2009
MERRA	1.25° × 1.25°	YES	01 June 2009 – 31 August 2009
SP-CAM	2.5° × 2.0° Embedded 2D CRM with 64 columns of 4 km resolution	NO	01 September – 30 November for the years 1998–2001

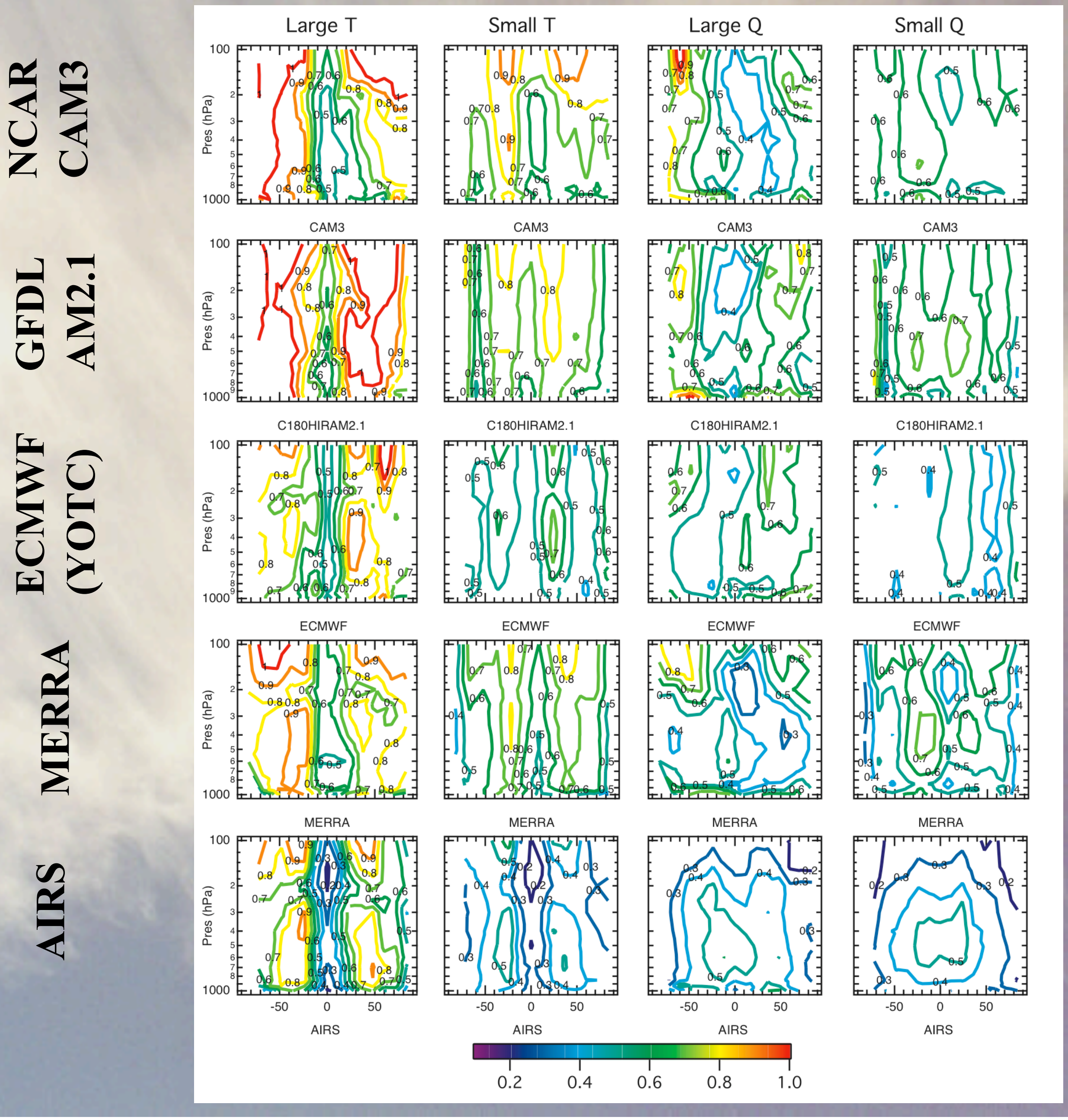
Kahn et al. (2011), submitted to *J. Clim.*

Model variance too low at small scales



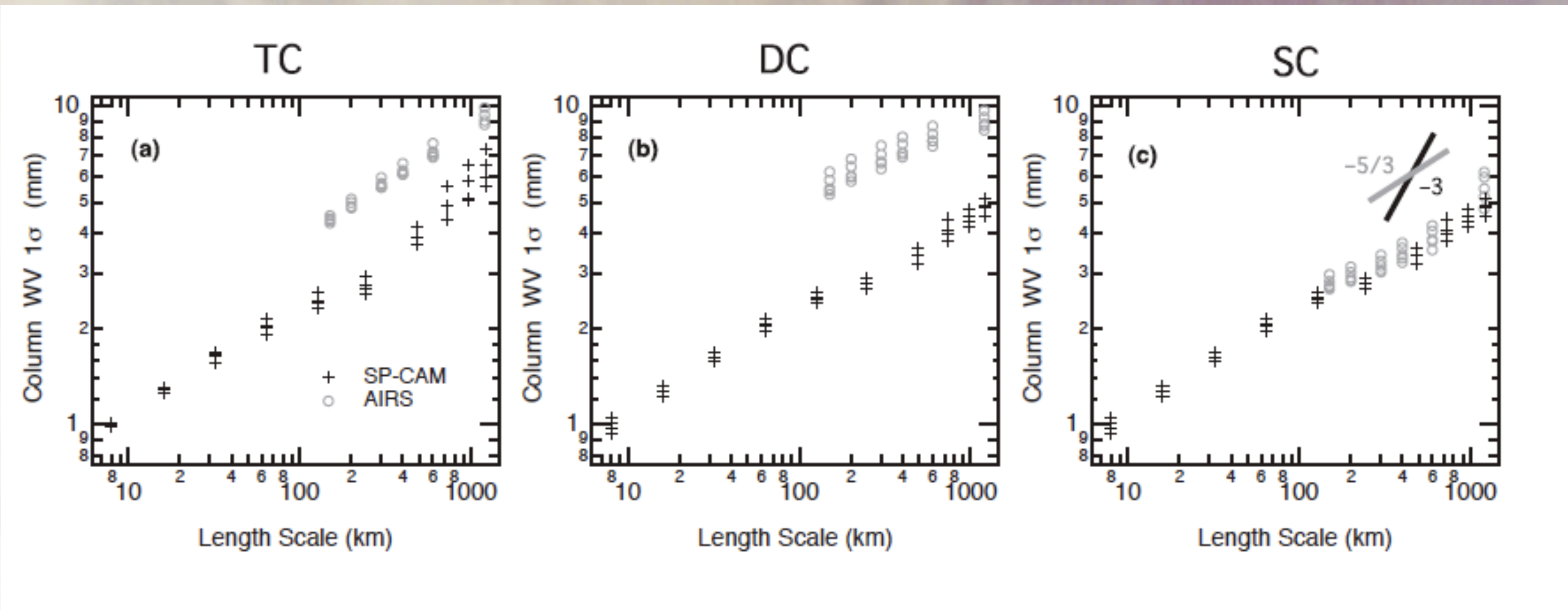
Kahn et al. (2011), submitted to *J. Clim.*

Models with data assimilation closer to AIRS



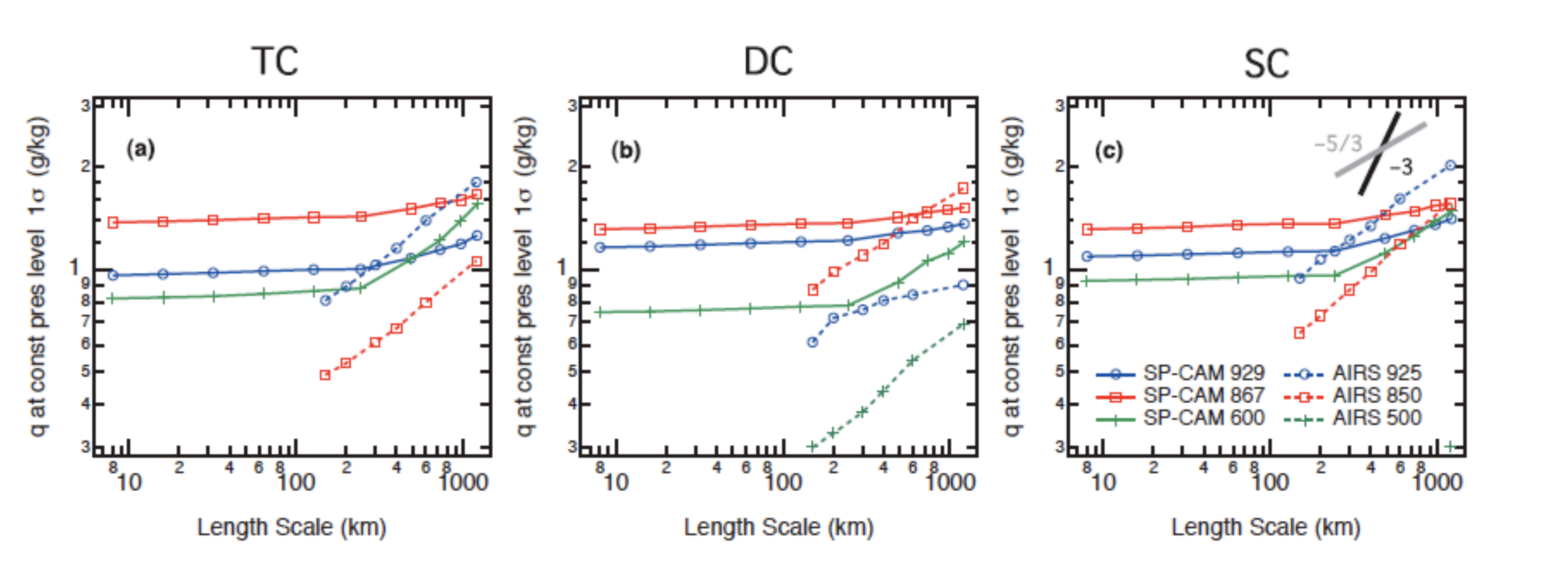
Kahn et al. (2011), submitted to *J. Clim.*

CWV Scaling Differences for AIRS and MMF



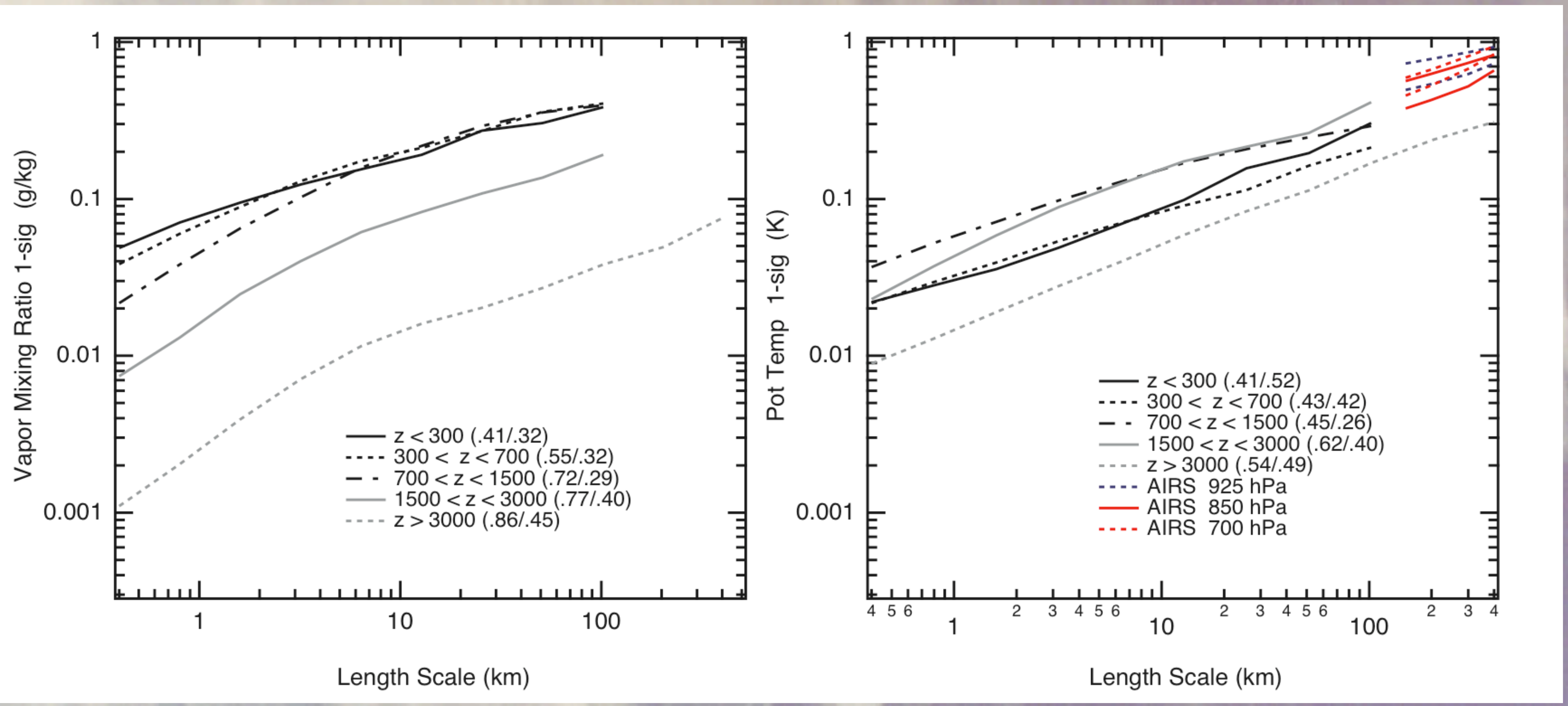
Kahn et al. (2011), submitted to *J. Clim.*

Height-Resolved *q* Scaling Differences for AIRS and MMF



Kahn et al. (2011), submitted to *J. Clim.*

VOCALS-Rex Scaling Breaks in *T* and *q*



Kahn et al. (2011), submitted to *J. Clim.*

Take Home Messages

- **AIRS scaling reveals lots of structure in *T* and *q***

- **Comparisons of AIRS to Models**
  - All models have scaling exponents that are too steep
  - "Free-running" model exponents > those with "data assimilation"

- **Scale breaks at scales below AIRS in models and obs**
  - MMF shows CWV break around resolution limits of AIRS
  - Also true with height-resolved *q* (not shown)
  - VOCALS *T* and *q* have increasing slopes below 10–20 km – around scales of stratocumulus cloud elements

- **Need higher spatial resolution sat obs – not planned for NPOESS era**
  - Scale-dependent variability – is the "turbulence" right in climate models?
  - Importance of subgrid-scale variability in modeling (e.g., Cusack et al. 1999)
  - Also critical role for *in situ* aircraft and surface observations (Pressel et al. 2010)